Penn State 9/27/02
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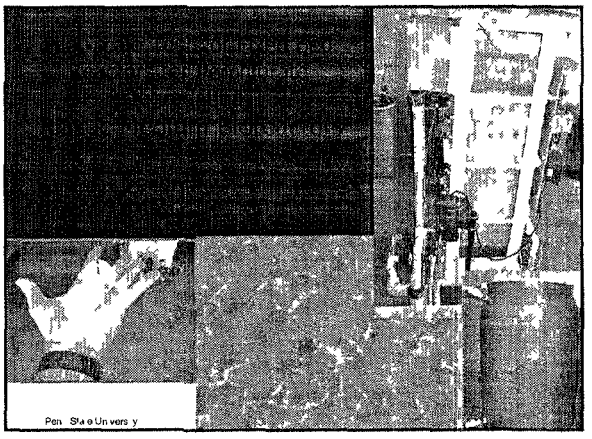

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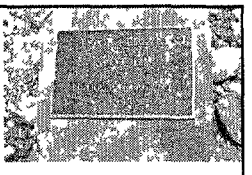
Study Participants



- Site Redlands California, Texas St well field
- Engineering Firm Camp, Dresser and McKee
- Research Unit The Pennsylvania State University
- Funding Agency American Water Works Association Research Foundation (AWWARF, via an EPA Grant)

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Plastic Medium Bioreactor

- System configuration
- Performance during six-month field tests in Redlands CA
- Reactor scale up- effect of dispersion in a packed bed reactor
- Reactor performance compared with other studies
- Stability of the bacterium used for inoculation

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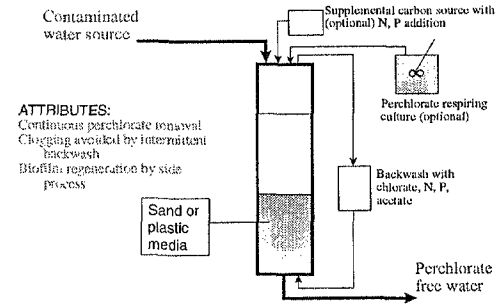
PSU-O4 Process Patent: Perchlorate degradation in a fixed bed bioreactor (U.S. Pat. No. 6214607)



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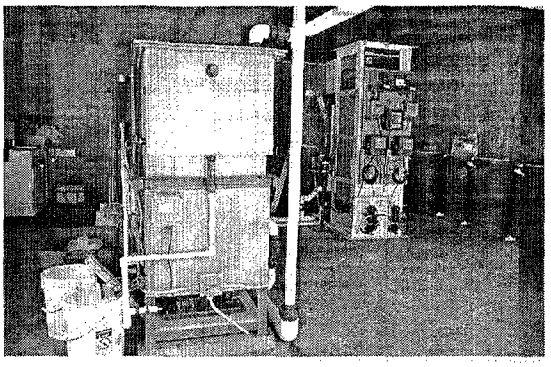

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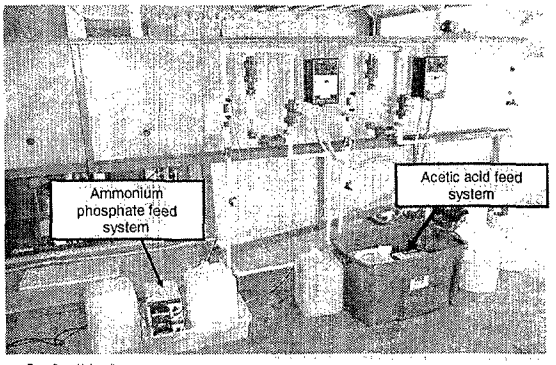
Filter inlet controls mounted in storage tank



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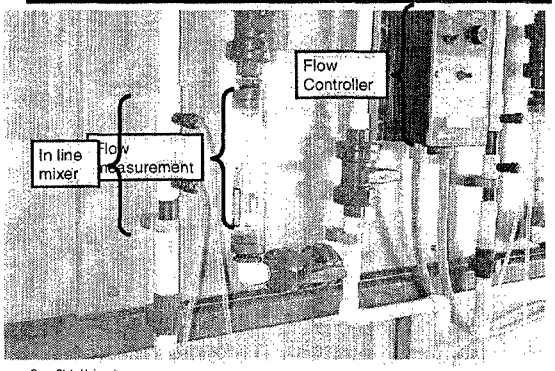
In line mixers, flow measurement, and flow controller



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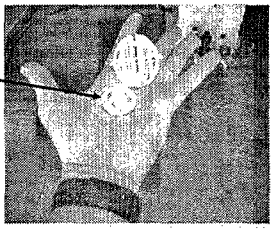
Plastic Media used in Reactor

Tri-Pack Plastic Media
(3.175 cm diameter)



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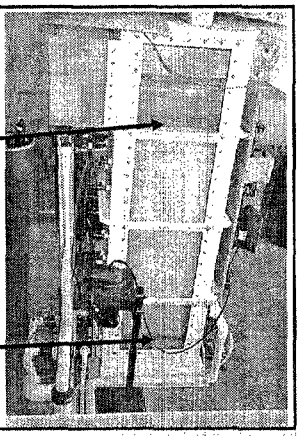
Plastic medium *bioreactor*

Media is held in place by a perforated metal plate

Media floats in water, producing entrance region



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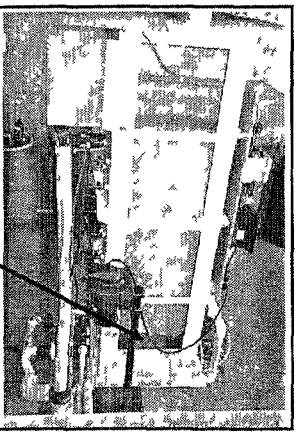
Plastic medium bioreactor



During backwashing *media falls down creating* a mixing zone

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Plastic Medium Bioreactor

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Groundwater Characteristics

Parameter	Value	Units
Perchlorate	50 - 120	ug/L
Nitrate	4-4 5	mg/L-N
Oxygen	8–10	mg/L
TCE	3-5	ug/L
1,1-DCE	1-2	ug/L

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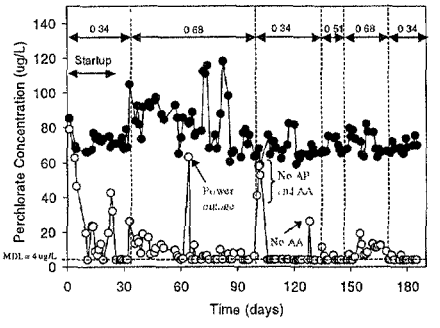
Perchlorate Removal: All Data



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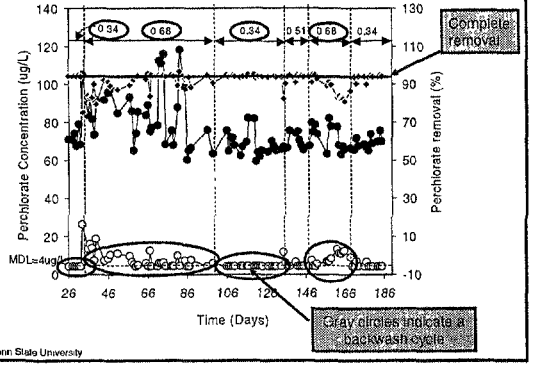
Perchlorate removal: Proper operation



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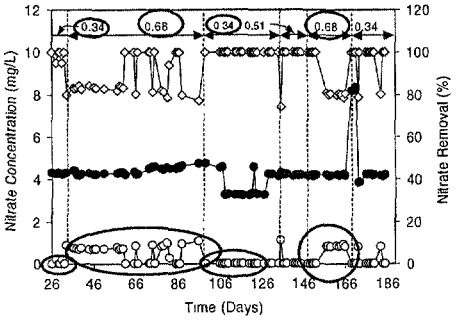
Nitrate Removal



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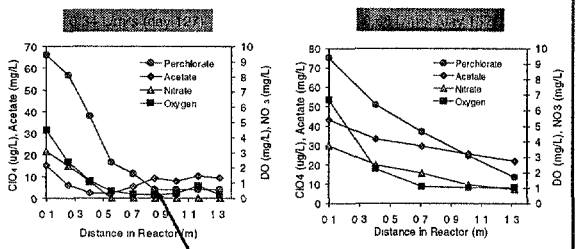
Chemical Profiles in Reactor



Perchlorate removed by 0.9 m
(slightly over half way in the reactor)

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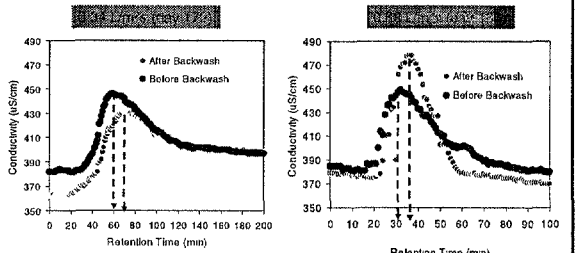
Detention Time Measurements



Before backwash: 60 min
After backwash. 70 min

Before backwash: 32 min
After backwash: 37 min

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Acetic acid and Nutrients

Measurements	Influent	Effluent
Acetic acid	51 ±9	21 ±8
pH	6.72 ±0.12	6 80 ±0.19
Phosphate	12.8 ±3.6	12.1 ±2.6
DOC (mg/L)- g.w.	0.28	----
- reactor	18 ±5	8.3 ±5.6
Turbidity (NTU)	----	3.39 ± 3.75

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Summary of Other Water Parameters

Measurements	Influent	Effluent
Temperature (°C)	19 7 ±0 7	19 4 ±0 7
Conductivity (µS/cm)	394 ±9	378 ±36
Dissolved Oxygen (mg/L)	8 7 ±0 4	0 2 ±0 3
ORP (mV)	8 ±52	-85 ±77
Sulfate	33 ±2	----
1,1-Dichloroethene (µg/L)	1 2 ±0 2*	1 3 ±0 2
Trichloroethene (µg/L)	3 7 ±0 5*	3 5 ±0 6

* Groundwater prior to amendments (data after day 26)

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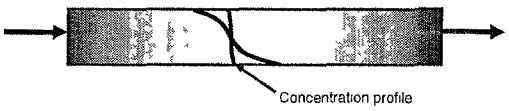
Effect of Dispersion on Performance



- Dispersion results in some fraction of the material to be in the reactor less time: result is less treatment
- Importance of dispersion can be evaluated from the magnitude of the Peclet number (Pe)
- To calculate Pe, need to measure dispersion coefficient (E).

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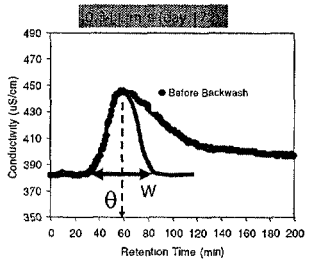
E can be calculated from detention time (θ) measurements



The Dispersion coefficient is calculated as

$$w = 6(2E\theta)^{1/2}$$

The Peclet number is calculated as

$$Pe = \frac{uL}{\theta}$$

u= water velocity

L= length of column

Results of Peclet Number Calculations

- Dispersion is important when Pe<5.
- In plastic medium reactor, Pe ranged from XX to YY
- In sand reactor, Pe ranged from 22 to 140.
- Based on these results, dispersion was not important for overall rate of reaction (only critical factor was detention time).

Plastic Medium Bioreactor

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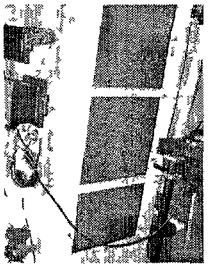
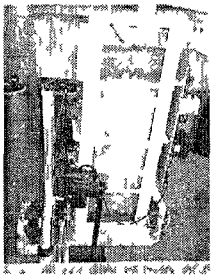
Which Fixed Bed Reactor is Better?

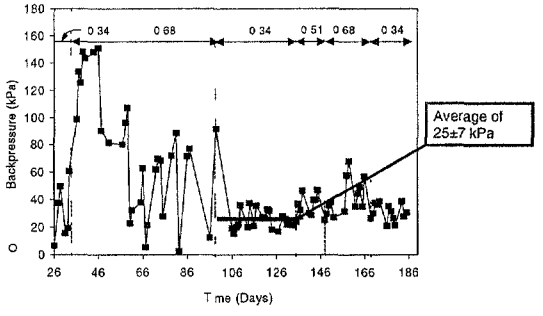
Sand media reactor



Plastic media reactor



Backpressure measurements



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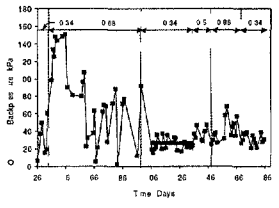
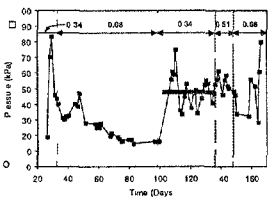
Backpressure: Plastic vs Sand

Plastic media



Average of 25±7 kPa

Sand media



Average of 50±11 kPa

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Reactor Kinetics: Removal Rates

- Expect removal rate, R, is 1st-order with respect to perchlorate concentration.
- Rate calculated as:

$$R = \frac{(Cin - Cout)}{\theta}$$

- For 1st-order kinetics, use log mean perchlorate concentration

$$C_{lm} = \frac{C_{in} - C_{out}}{\ln (C_{in} / C_{out})}$$

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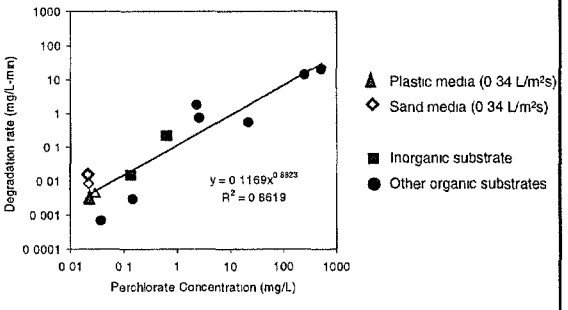
Rates in Plastic and Sand Medium Reactors vs Other studies



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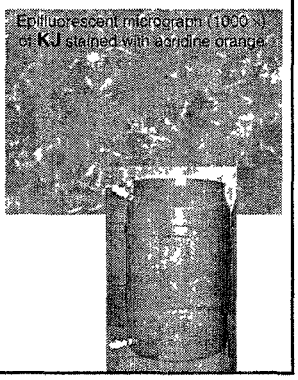
Did *Dechlorosoma* sp. KJ survive?

- Reactor inoculated with a pure culture
- Other bacteria present in groundwater
- Sterile conditions not maintained
- Electron acceptors present in order: oxygen>nitrate>> perchlorate



Preliminary community analysis

CONCLUSIONS

- Perchlorate (and nitrate) were completely removed in a plastic medium bioreactor at a hydraulic loading rate of 0.34 L/m^2-s (0.5 gpm/ft^2)
- Backwashing once a week was needed to prevent excessive biofilm buildup
- Perchlorate was removed at the same time as nitrate
- Community analysis indicates that the inoculated microbe was only a part of a diverse biofilm community that developed in the reactor.

ACKNOWLEDGMENTS

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Camp, Dresser & McKee, Inc	Allyson Chu, Steven Price, Stephen Liao, Harold Pepple, Dick Corneille, Mike Zaefer
Students	Booki Min, Yanguang Song, Husen Zhang,
Funding	AWWARF Project manager Frank Blaha

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Logan B E K Kim and S Price 2001 *In* Bioremediation of Inorganic Compounds, A Leeson et al eds Battelle Press Columbus, OH 6(9) 303-308

Evans P , A Chu S Liao S Price B Min and B E Logan 2002 Proc Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 20 23, Monterey, CA *In press*

Min, B P Evans, A Chu and B E Logan Perchlorate remveal ina pilot plant scale packed bed bioreactor 2 Plastic medium b oreactor *Submitted*